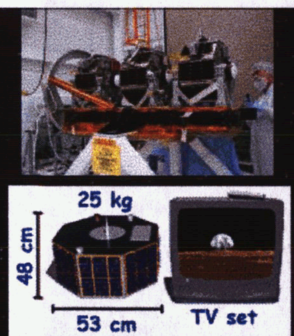
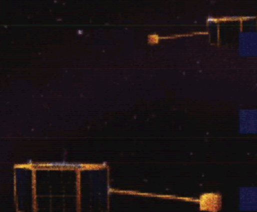
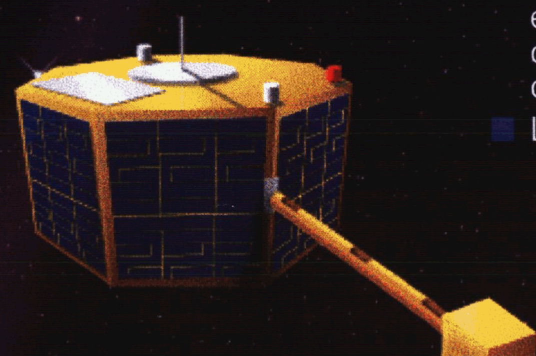
ST-5 Overview

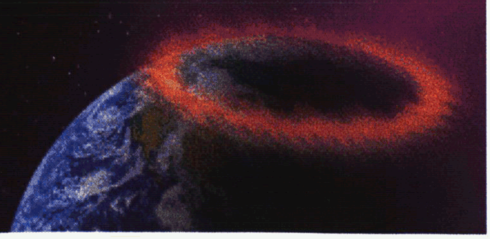


Not much bigger than a large birthday cake or a small TV.



- ST-5 is a three satellite (micro-sat) constellation
- NASA New Millennium Program technology validation mission
- Help scientists understand the Earth's magnetosphere and its effect on space weather
- Uses the GMSEC architecture to enable cost-effective model-based operations to run the ST-5 constellations lights-out
- Launched March 22, 2006
  - Three month base mission
  - Possible mission extension





Space Technology 5
Tomorrow's Technology Today

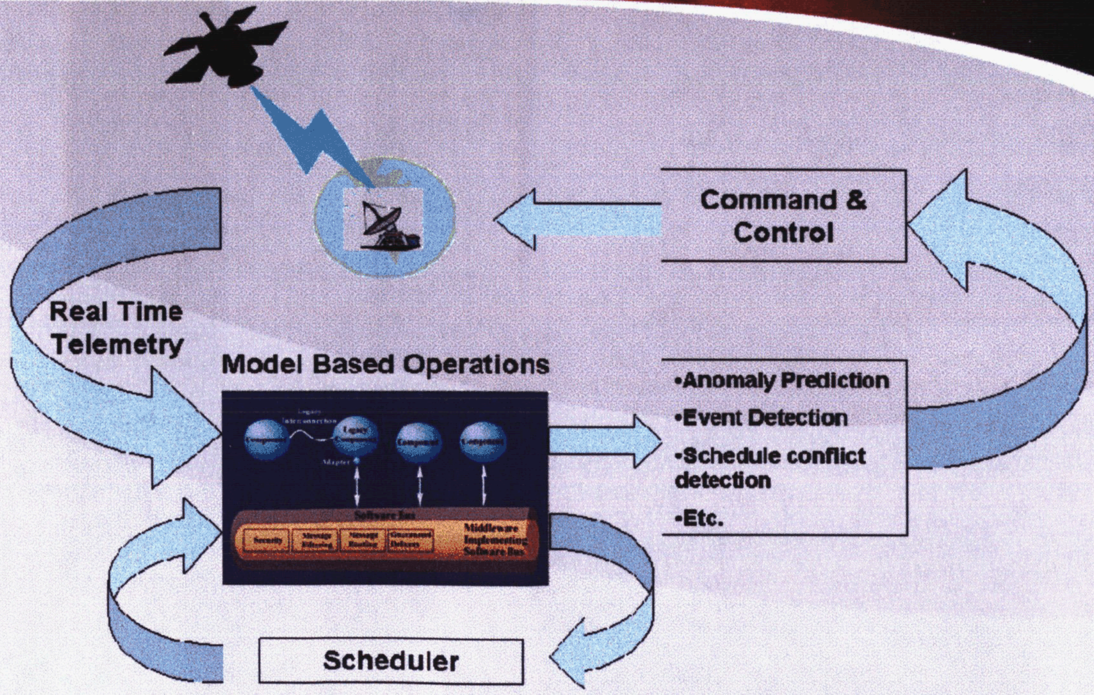
What we need to make this happen

- Transition from centralized mission control to distributed control
- Self-managing software components (autonomic computing)
    - (1) Components have self-awareness
    - (2) Self-optimizes
    - (3) Self-healing
    - (4) Self-protection
    - (4) Negotiates (peer-to-peer) for resources
    - (5) Functions in a heterogeneous world and with open standards
    - (6) Anticipates needed resources and hides details needed to obtain resources
- ST-5 mission will demonstrate parts of (1), (2), (4), (5) and (6)
    - Lights-out operations with model-based software
        - Predict problems before they happen and fix early
        - Models update themselves automatically
        - Modeling system is built on top of "plug and play" architecture to enable easy extensibility
    - Act as stepping stone for this type of capability for future missions
    - Possibly extend capabilities during the extended mission phase

Historical Background for for Model-Based Operations at GSFC

- 1987 ESP – time varying limits for GRO; Shendock, Mandl, Carlton
  - Attempted to more closely monitor telemetry alerts over orbit's worth of data and identify failure trends
- Mid- 1990's Altair – Model-based operations approach for MAP and IMAGE; Coyle, Shendock
  - State model to monitor health and safety of MAP and IMAGE, too expensive to maintain
- 2004-2006 – Self updating model-based operations on ST-5 constellation; Shendock, Witt, Stanley, Mandl et. Al.
  - Cost effective model to monitor health and safety since model can update self via telemetry and use GMSEC message bus to initiate correction actions

ST-5 Model-Based Operations Overview

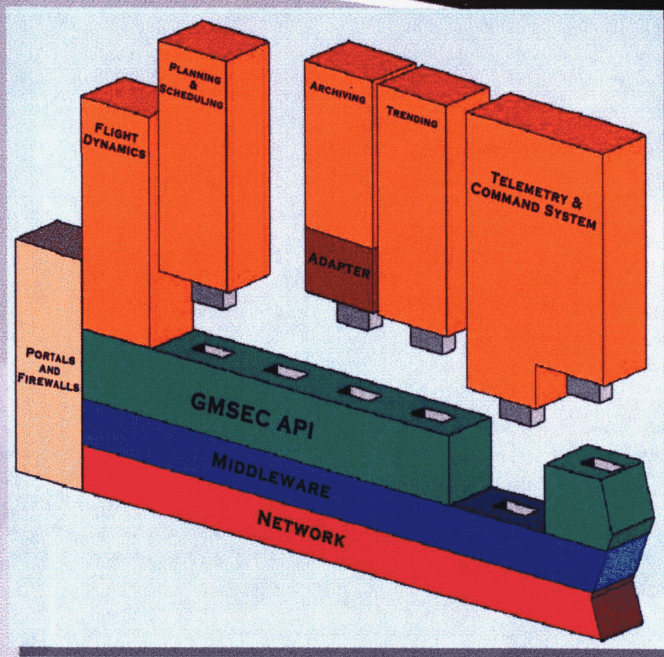


Underlying "Plug and Play" Message Bus Architecture-- Goddard Mission Services Evolution Center (GMSEC)

GMSEC architecture provides a scalable and extensible ground and flight system approach

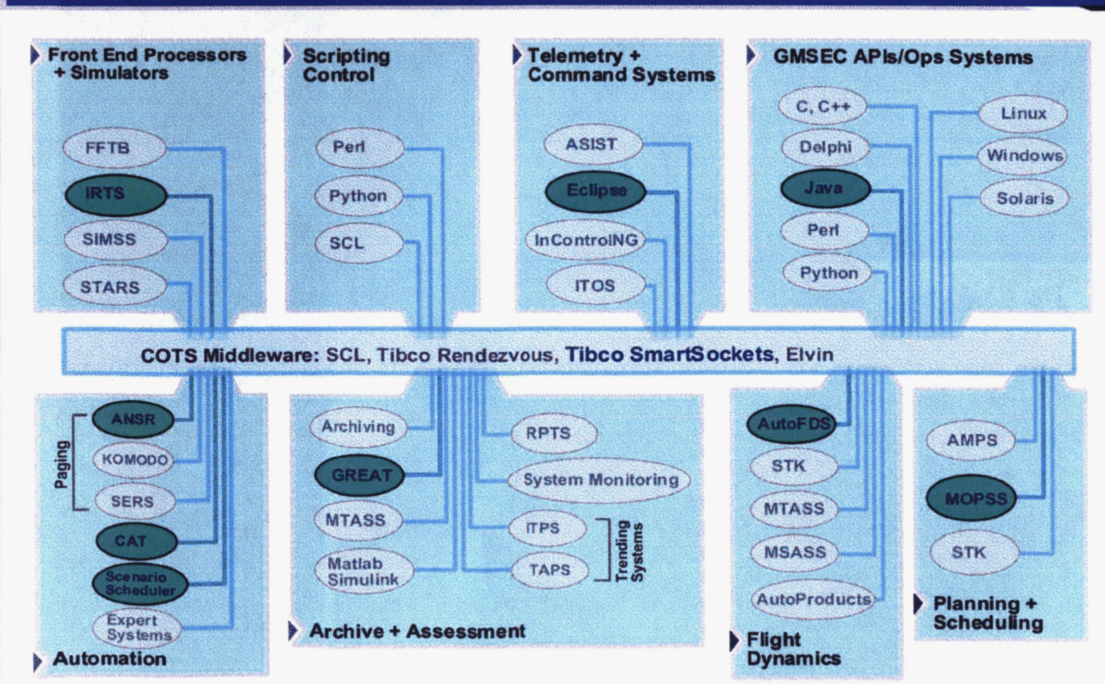
- Standardized messages formats
- Plug-and-play components
- Publish/Subscribe protocol
- Platform transparency

More info at: http://gmsec.gsfc.nasa.gov



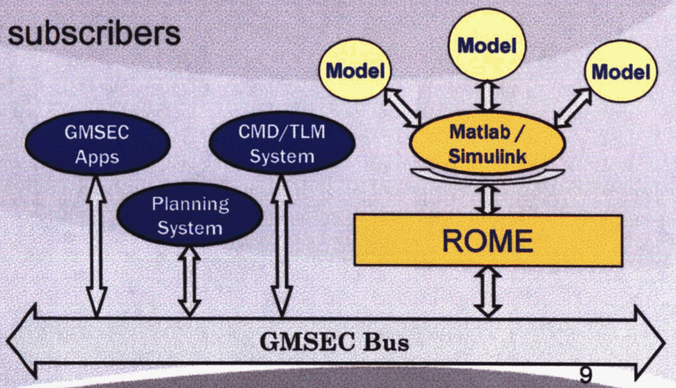
GMSEC Component Catalog

GMSEC approach gives users choices for the components in their system. The TRMM mission has selected key components from the GMSEC catalog.



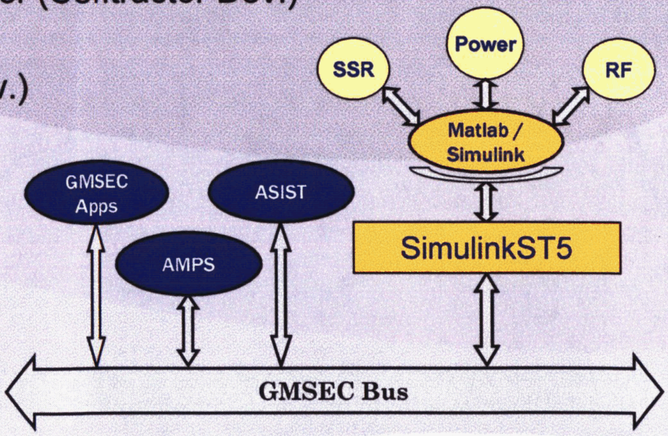
ROME Framework

- Real-time Object Modeling Executive
- Support multiple models and multiple spacecraft
- Leverage common engineering modeling environments
- Models from various sources are easily integrated
- Fully supports GMSEC bus
- Models initialized and maintained from telemetry
- Model control via configuration file or bus directive
- Results available to GMSEC subscribers
- Easily configured via XML
- Highly scalable



ST5 Specific Configuration

- ROME based implementation
- Dynamic characterization of sub-systems phenomenology
- Used by mission to manage constrained resources
- Models of Subsystems
  - Solid State Recorder (Contractor Dev.)
  - RF (Student Dev.)
  - Power (Project Dev.)



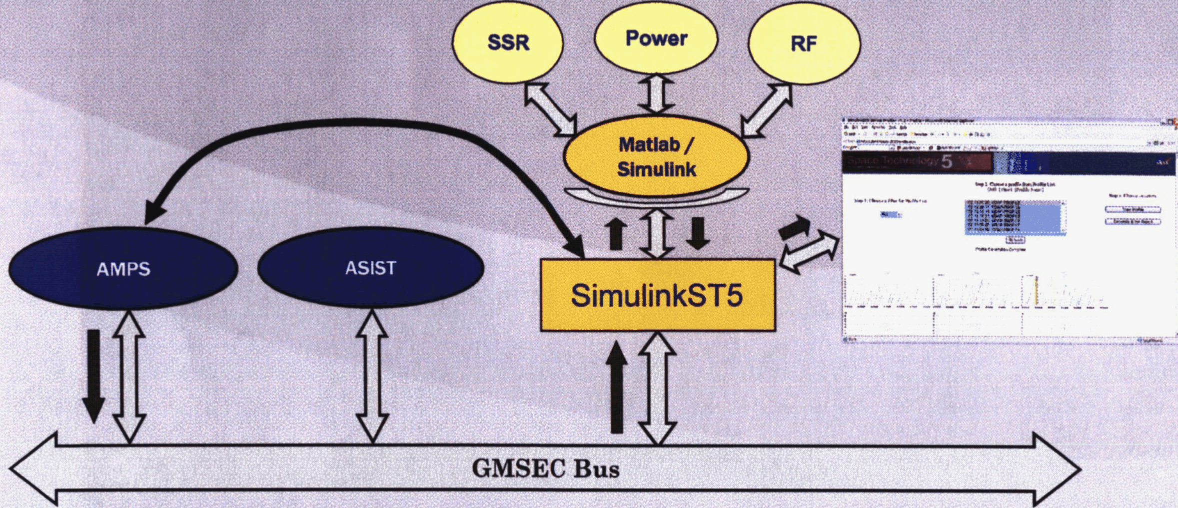
SimulinkST5 GMSEC Highlights

- Standardized messaging interoperability
- GMSEC Compliance
  - Directives
    - AMPS
    - ASIST
  - Mnemonic Value Messages
    - ASIST
    - ITOS capability
  - Heartbeat messages
  - Log messages
  - Product Messages
- Predictive Model-Based Operations
  - Subsystem models to anticipate platform conditions in a constellation environment.
    - **Support Short and Long Term Mission Planning**
  - Interact with AMPS and ASIST for control directives, telemetry, and profile events.
- Constellation Operations Support

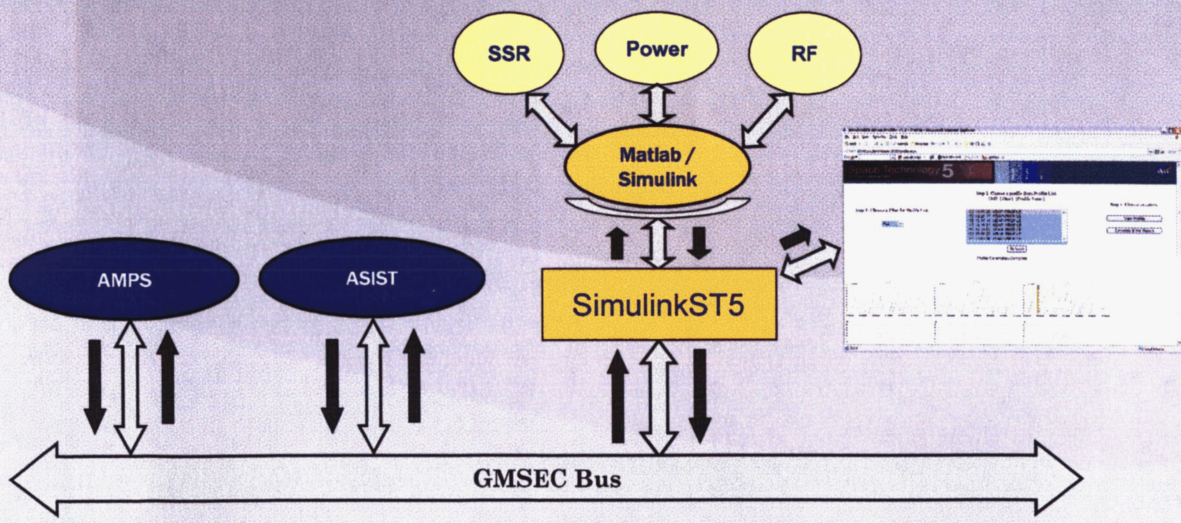
Advantages

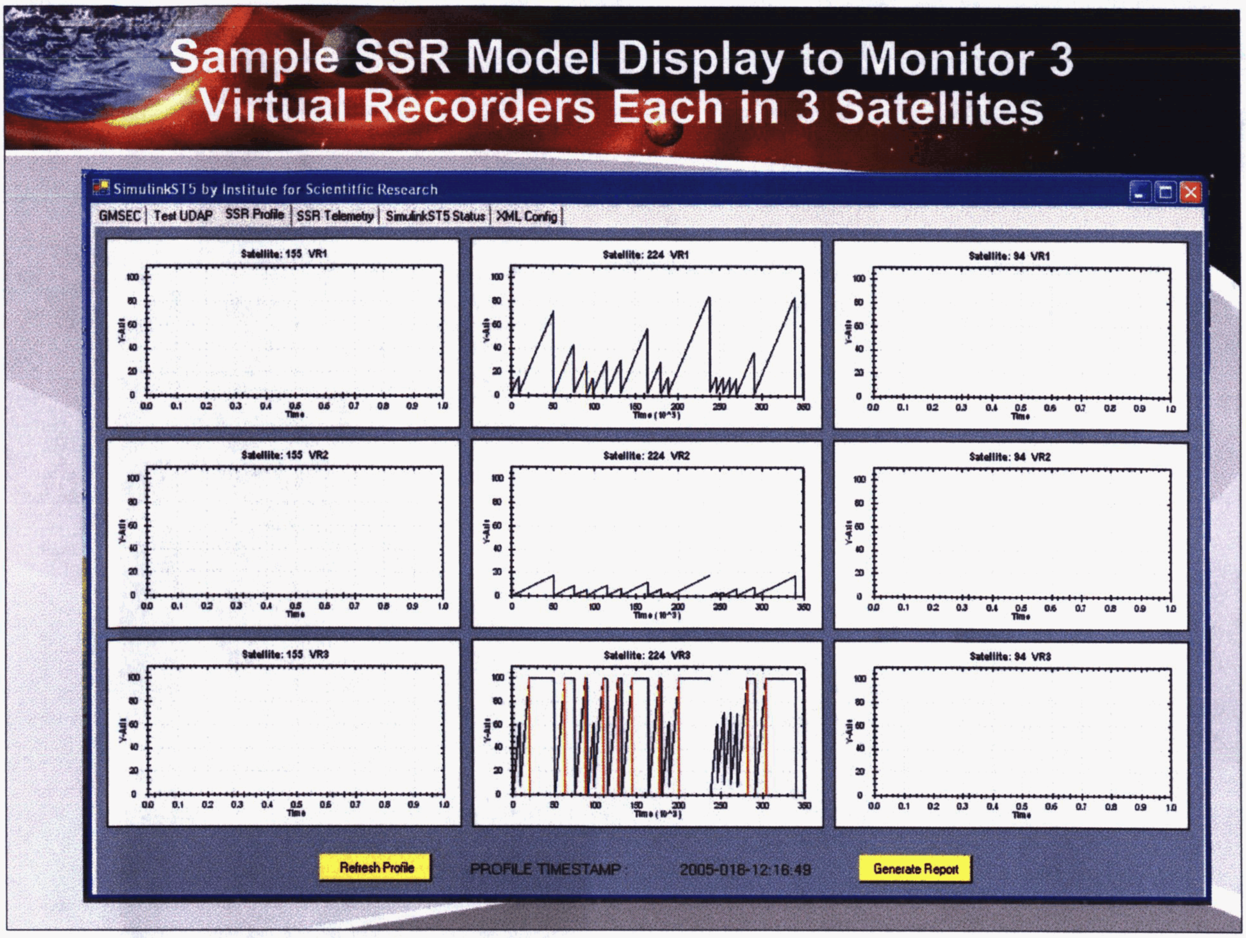
- Mission Planning Support
  - Offline Profile– Entire duration of operational plan
  - Real-time Profile– 4 days from current point in time
    - Configurable via XML
- User Interface
  - SimulinkST5 console
  - Web interface
    - Configured for MOC access only
- Increases ability to move toward Autonomous Operations
  - Reduce resources needed to perform analysis

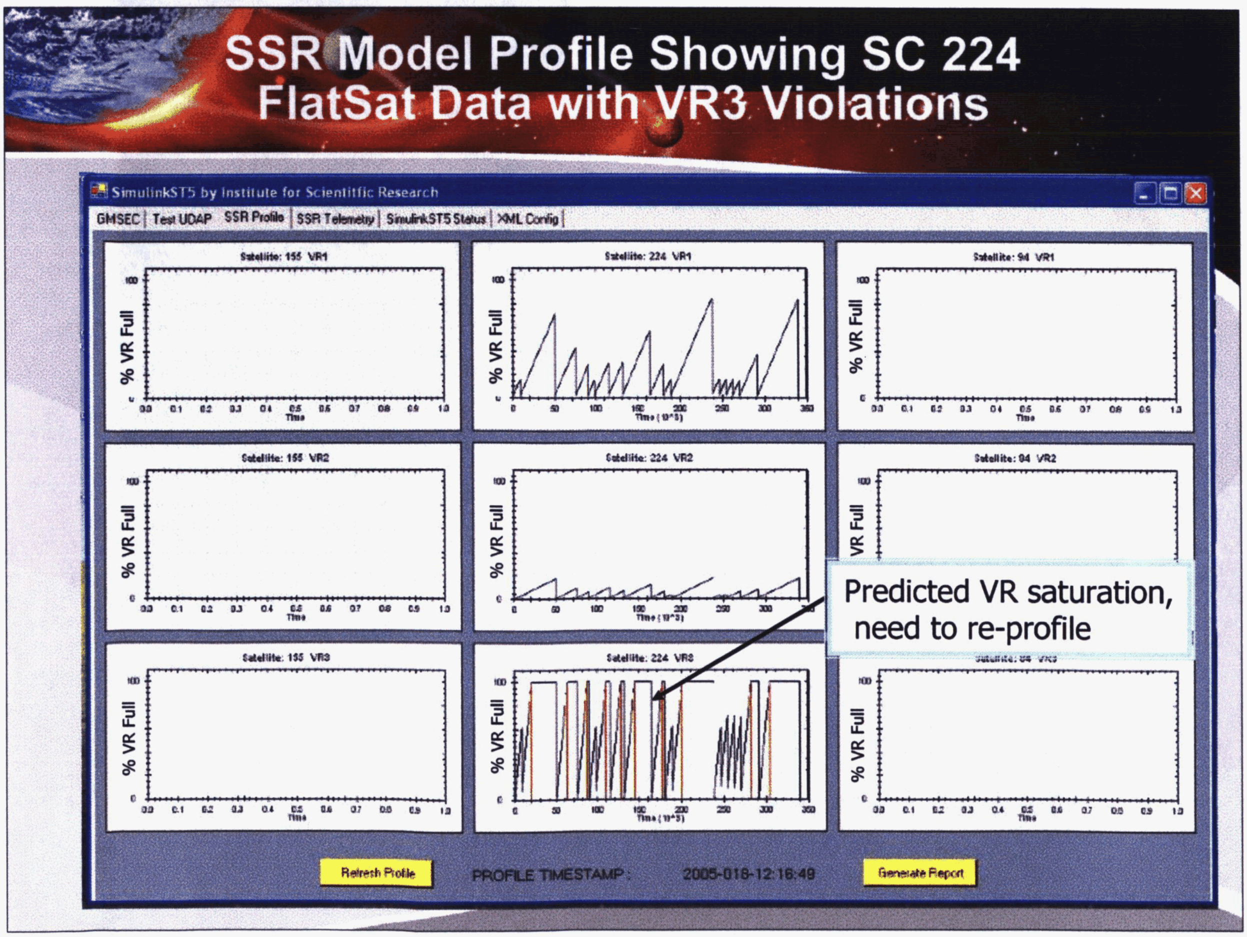
Long Term (Plan) Validation Flow



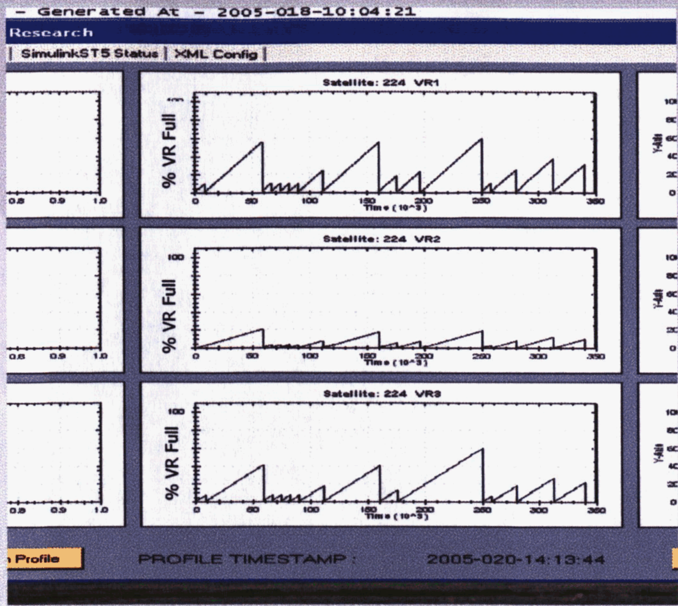
Real-time Profile Flow




Sample SSR Model Display to Monitor 3 Virtual Recorders Each in 3 Satellites
SimulinkST5 by Institute for Scientific Research
GMSEC | Test UDAP | SSR Profile | SSR Telemetry | SimulinkST5 Status | XML Config
Satellite: 155 VR1
Satellite: 224 VR1
Satellite: 94 VR1
Satellite: 155 VR2
Satellite: 224 VR2
Satellite: 94 VR2
Satellite: 155 VR3
Satellite: 224 VR3
Satellite: 94 VR3
Refresh Profile
PROFILE TIMESTAMP:
2005-018-12:16:49
Generate Report


SSR Model Profile Showing SC 224 FlatSat Data with VR3 Violations
SimulinkST5 by Institute for Scientific Research
GMSEC | Test UDAP | SSR Profile | SSR Telemetry | SimulinkST5 Status | XML Config
Satellite: 155 VR1
Satellite: 224 VR1
Satellite: 94 VR1
Satellite: 155 VR2
Satellite: 224 VR2
Satellite: 94 VR2
Satellite: 155 VR3
Satellite: 224 VR3
% VR Full
Predicted VR saturation, need to re-profile
Refresh Profile
PROFILE TIMESTAMP:
2005-018-12:16:49
Generate Report

SSR Model Profile After Commands Issued to FlatSat to Repartition SSR



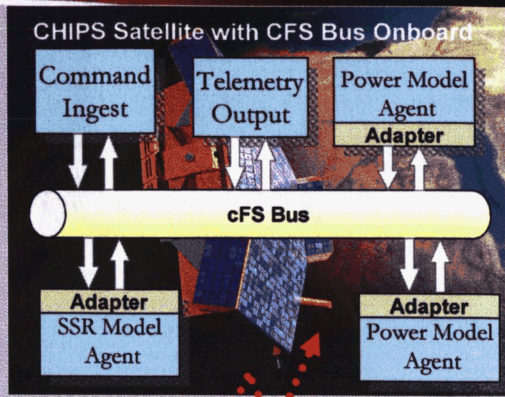
- Re-profile command was issued to eliminate future VR violations (i.e. early saturation of VR capacity)
- New profile for VRs in question displayed showing that no VR saturations predicted with new profile

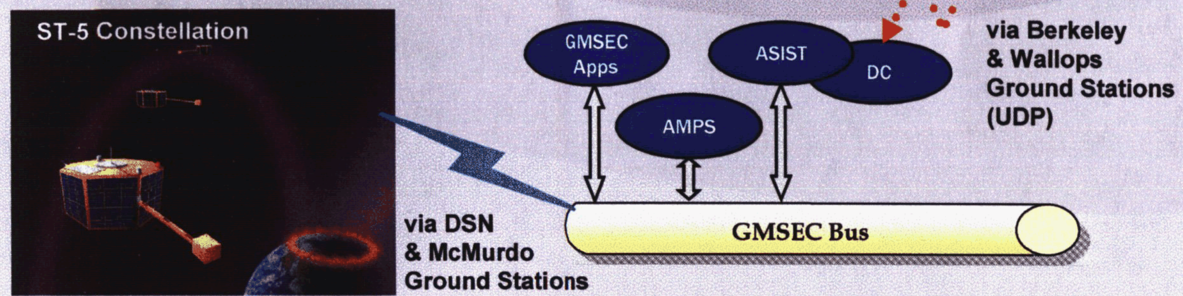
Possible Future Extensions of this Experiment in Extended Mission

- Transform predictive models into mobile agents that can run on the ground or spacecraft
  - Can be easily moved if desired, to another space-based or ground platform
- Simulate discovering needed service from another satellite and then requesting service
  - Move Simulink–based ROME models to Cosmic Hot Interstellar Plasma Spectrometer (CHIPS) environment
  - Run lights-out models from autonomy flight testbed, CHIPS testbed and CHIPS
- Build SensorML wrapper for ST-5 and allow ST-5 to discover predictive modeling service

Moving Models Onboard CHIPS Satellite Under cFS to Demonstrate as Mobile Agents

- Models transformed into mobile agents
  - Working with SSR agent first
- Adapter built to make compatible with both GMSEC and Core Flight System (CFS)
- Demonstrate capability to move software running on GMSEC, moved onboard to run under CFS
- Beginning step to transform missions from central control to distributed control via self-managing software





CHIPS – Cosmic Hot Interstellar Plasma Spectrometer
ST-5 – Space Technology 5

DC – Data Center
ASIST – Advanced Spacecraft Integration and System Test